PhD THESIS ABSTRACT

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Title: **Space-Time Evolution of the Intraseasonal Variability in the Indian Summer Monsoon and its Association with Extreme Rainfall Events: Observations and GCM Simulations**

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In this thesis, we investigated modes of intraseasonal variability (ISV) observed in the Indian monsoon rainfall and how these modes modulate rainfall over India. We identified a decreasing trend in the intensity of low-frequency intraseasonal mode with increasing strength in synoptic variability over India. We also made an attempt to understand the reason for these observed trends using numerical simulations.

In the first part of the thesis, satellite rainfall estimates are used to understand the spatiotemporal structures of convection in the intraseasonal timescale and their intensity during boreal summer over south Asia. Two dominant modes of variability with periodicities of 10–20-days (high-frequency) and 20–60-days (low-frequency) are found, with the latter strongly modulated by sea surface temperature. The 20–60-day mode shows northward propagation from the equatorial Indian Ocean linked with eastward propagating modes of convective systems over the tropics. The 10–20-day mode shows a complex space-time structure with a northwestward propagating anomalous pattern emanating from the Indonesian coast. This pattern is found to be interacting with a structure emerging from higher latitudes propagating southeastwards. This could be related to vertical shear of zonal wind over northern India. The two modes exhibit variability in their intensity on the interannual time scale and contribute a significant amount to the daily rainfall variability in a season. The intensities of the 20–60-day and 10–20-day modes show significantly strong inverse and direct relationship, respectively, with the all-India June–September rainfall. This study also establishes that the probability of occurrence of substantial rainfall over central India increases

significantly if the two intraseasonal modes simultaneously exhibit positive anomalies over the region. There also exists a phase-locking between the two modes.

In the second part of the thesis, we investigated the changing nature of these intraseasonal modes over Indian region, and their association with extreme rainfall events using ground based observed rainfall. We found that the relative strength of the northward propagating 20–60-day mode has a significant decreasing trend during the past six decades, possibly attributed to the weakening of large-scale circulation in the region during monsoon. This reduction is compensated by a gain in synoptic-scale (3–9 days) variability. The decrease in the low-frequency ISV is associated with a significant decreasing trend in the percentage of extreme events during the active phase of the monsoon. However, this decrease is balanced by a significant increasing trend in the percentage of extreme events in break phase. We also find a significant rise in occurrence of extremes during early- and late-monsoon months, mainly over the eastern coastal regions of India. We do not observe any significant trend in the high-frequency ISV.

In the last part of the thesis, we used numerical simulations to understand the observed changes in the ISV features. Using the atmospheric component of a global climate model (GCM), we have performed two experiments: control experiment (CE) and heating experiment (HE). The CE is the default simulation for 10 years. In HE, we prescribed heating in the atmosphere in such a way that it mimics the conditions for extreme rainfall events as observed over central India during June–September. Heating is prescribed primarily during the break phase of the 20–60-day mode. This basically increases the number of extremes, majority of which are in break phase. The design of the experiment reflects the observed current scenario of increased extreme events during breaks. We found that the increased extreme events in the HE decreased the intensity of the 20–60-day mode over the Indian region. This reduction is associated with a reduction of rainfall in active phase and increase in the length of break phase. A reduction in the seasonal mean over India is also observed. The reduction of active phase rainfall is linked with an increased stability of the atmosphere over central India. Lastly, we propose a possible mechanism for the reduction of rainfall in active phase. We found that there is a significant reduction in the strength of the vertical easterly shear over the northern Indian region during break–active transition phase. This basically weakens the conditions for the growth of Rossby wave instability, thereby elongating break phase and reducing the rainfall intensity in the following active phase.

This study highlights the redistribution of rainfall intensity among periodic (low-frequency) and non-periodic (extreme) modes in a changing climate scenario, which is further tested in a modeling study. The results presented in this thesis will provide a pathway to understand, using observations and numerical model simulations, the ISV and its relative contribution to the Indian summer monsoon. It can also be used for model evaluation.